4.3 NOTATION

Revise the following definitions:

d_e = distance from the centerline of the exterior web of exterior beam to the interior edge of curb or traffic barrier (ft.)

K = effective length factor for columns and arch ribs; constant for different types of construction; effective length factor for columns in the plane of bending (4.5.3.2.2b) (4.5.3.2.2c) (4.6.2.2.1) (4.6.2.5)

ϕ = ~~resistance factor for axial compression;~~ rotation per unit length (~~4.5.3.2.2b~~ C4.6.6)

ϕ_K = stiffness reduction factor = 0.75 for concrete members, and = 1.0 for steel and aluminum members (4.5.3.2.2b)

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4.4 ACCEPTABLE METHODS OF STRUCTURAL ANAYSIS

Delete paragraph three:

~~The name, version, and release date of software used should be indicated in the contract documents.~~

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4.6.2.2 BEAM-SLAB BRIDGES

4.6.2.2.1 Application

Revise paragraph six as follows:

Bridges not meeting the requirements of this article shall be analyzed as specified in Article 4.6.3, or as directed by the Design Office Chiefs at the Type Selection Meeting.

C4.6.2.2.1

Revise paragraph eight as follows:

Whole-width design is appropriate for torsionally-stiff cross-sections where load-sharing between girders is extremely high and torsional loads are hard to estimate. Prestressing force should be evenly distributed between girders. Cell width-to-height ratios should be approximately 2:1. The distribution factors for exterior girder moment are not used because the difference in total number of design lanes doesn't change appreciably when doing so. The two or-more-lanes loaded distribution factors for exterior girder shear are not used because, at most, a 4% increase would occur due to the range-of-applicability of d_e. The one-design-lane-loaded distribution factor for exterior girder shear is not used because lever rule isn't appropriate for use in multi-cell boxes.

4.6.2.2.2e Skewed Bridges

Delete paragraph one:

~~When the line supports are skewed and the difference between skew angles of two adjacent lines of supports does not exceed 10°, the bending moment in the beams may be reduced in accordance with Table 1.~~

C4.6.2.2.2e

Revise paragraph one as follows:

Accepted reduction factors are not currently available for cases not covered in Table 1. <u>Caltrans presently does not take advantage of the reduction in load distribution factors for moment in longitudinal beams on skewed supports.</u>

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4.6.2.2.3c Skewed Bridges

Add a new paragraph as follows:

In California, load distribution factors calculated from Table 4.6.2.2.3a,b-1 shall be modified according to Bridge Design Aids 5-31 through 5-38.

C4.6.2.2.3c

Add a new paragraph as follows:

The skew modification factors used by Caltrans for the exterior girder are more conservative. Experience has shown that interior girders do not require modification.

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4.6.2.2.5 Special Loads with other Traffic

Revise the first paragraph as follows:

Except as specified herein, the provisions of this article may be applied where the approximate methods of analysis for the analysis of beam-slab bridges specified in Article 4.6.2.2 and slab-type bridges specified in Article 4.6.2.3 are used. The provisions of this article shall not be applied where either:

- the lever rule has been specified for both single lane and multiple lane loadings, or
- the special requirement for exterior girders of beam-slab bridge cross-sections with diaphragms specified in Article 4.6.2.2.2d has been utilized for simplified analysis.
- Two identical permit vehicles in separate lanes are used, as specified in CA amendment to Article 3.4.1.

C4.6.2.2.5

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4.6.2.5
Revise as follows:

Physical ~~column~~ lengths of compression members shall be multiplied by an effective length factor, *K*, to compensate for rotational and translational boundary conditions other than pinned ends.

~~In the absence of~~ In trusses and frames, a more refined analysis, where lateral stability is provided by diagonal bracing or other suitable means, the effective length factor in the braced plane, *K*, for the compression members shall be taken as unity, unless structural analysis shows a smaller value may be used. In the absence of a more refined analysis, the effective length factor in the braced plane for steel in ~~triangulated trusses,~~ trusses~~, and frames~~ may be taken as:

- For compression chords: $K = 1.0$
- For bolted or welded end connections at both ends: $K =$ ~~0.750~~ 0.850
- ~~For pinned connections at both ends: *K* = 0.875~~
- For single angles, regardless of end connection: $K = 1.0$

Vierendeel trusses shall be treated as unbraced frames.

C4.6.2.5
Revise paragraphs one and two as follows:

Equations for axial ~~the compressive~~ resistance of columns and moment magnification factors for beam-columns include a factor, *K*, which is used to modify the length according to the restraint at the ends of the column against rotation and translation.

K is ~~the ratio of the effective length of an idealized pin-end column to the actual length of a column with various other end conditions. *KL* represents the length between inflection points of a buckled column influenced by the restraint against rotation and translation of column ends~~. a factor that when multiplied by the actual length of the end-restrained compression member, gives the length of an equivalent pin-ended compression member whose buckling load is the same as that of the end-restrained member. The Structural Stability Research Council (SSRC) Guide (Galambos 1988) recommends $K = 1.0$ for compression chords on the basis that no restraint would be supplied at the joints if all chord members reach maximum stress under the same loading conditions. It also recommends $K = 0.85$ for web members of trusses supporting moving loads. The position of live load that produces maximum stress in the member being designed also results in less than maximum stress in members framing into it, so that rotational restraint is developed. Theoretical values of *K*, as provided by the Structural Stability Research Council, are given in Table C1 for some idealized column end conditions.

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4.6.2.6 Effective Flange Width

4.6.2.6.1 General

Revise as follows:

In the absence of a more refined analysis and/or unless otherwise specified, limits of the width of a concrete slab, taken as effective in composite action for determining resistance for all limit states, shall be as specified herein. The calculation of deflections should be based on the full flange width. For the calculation of live load deflections, where required, the provisions of Article 2.5.2.6.2 shall apply.

The effective span length used in calculating effective flange width may be taken as the actual span for simply supported spans and the distance between points of permanent load inflection for continuous spans, as appropriate for either positive or negative moments.

The effective flange width may be taken as:

If $S/L \leq 0.32$, then:

$$b_{eff} = b \qquad (4.6.2.6.1\text{-}1)$$

Otherwise:

$$b_{eff} = \left[1.24 - 0.74\left(\frac{S}{L}\right)\right] b \geq b_{min} \qquad (4.6.2.6.1\text{-}2)$$

where

b = full flange width (ft)

b_{eff} = effective flange width (ft)

b_{min} = minimum effective flange width (ft)

L = span length (ft)

S = girder spacing (ft)

Equations 1 and 2 shall be used within the limit of skew angle $\theta \leq 60^o$. For $\theta > 60^o$, unless a more refined analysis is performed, the effective flange width may be taken as b_{min} and shall not exceed the girder spacing.

C4.6.2.6.1

Revise as follows:

Longitudinal stresses in the flanges are spread across the flange and the composite deck slab by in-plane shear stresses. Therefore, the longitudinal stresses are not uniform. The effective flange width is ~~a reduced~~ the width over which the longitudinal stresses are assumed to be uniformly distributed and yet result in the same force as the nonuniform stress distribution would if integrated over the whole width.

The effective flange width provisions are based on state-of-the-art research by Chen, et al. (*2005*), Nassif et al. (*2005*), and Caltrans revisions. The concrete deck slabs shall be designed in accordance with Article 9.7.

The girder spacing and the full flange width are shown in Figure C1. For interior beams, the girder spacing, *S*, and the full flange width, *b*, shall be taken as the average spacing of adjacent beams. For exterior beams, the girder spacing, *S*, and the full flange width, *b*, shall be taken as the overhang width plus one-half of the adjacent interior beam spacing, and shall be limited to the adjacent interior beam spacing.

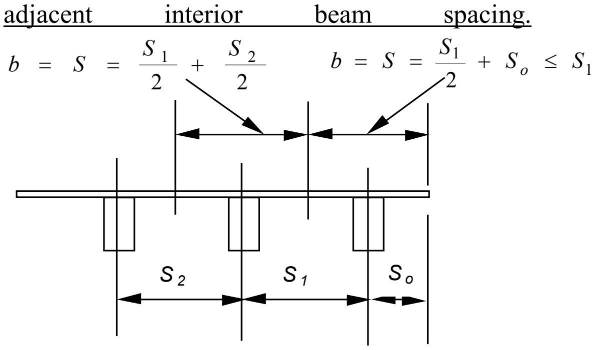

Figure C4.6.2.6.1-1 Girder Spacing and Full Flange Width.

The full flange width is proposed within the limits of the parametric study ($S \leq 16$ ft, $L \leq 200$ ft, $\theta \leq 60^o$) by Chen et al. (*2005*) based on an extensive and systematic investigation of bridge finite element models. The full flange width is also proposed within the limit of $S/L \leq 0.25$ by Nassif et al. (*2005*). For $S/L > 0.25$, Nassif et al. (*2005*) recommends that:

$$\frac{b_{eff}}{b} = 1.0 - 0.5\left(\frac{S}{L}\right) \qquad (C4.6.2.6.1\text{-}1)$$

Figure C2 shows a graphic illustration of Equation 1 which is a good combination of the effective flange width criteria proposed by Chen et al. (*2005*) and Nassif et al. (*2005*). For $S/L \leq 0.32$, the exact parametric study limit adopted by Chen et al. (*2005*), Equation 1 gives the full flange width. For $S/L = 1$, Equation 1 provides one-half of the full flange width which is as same as Equation C1.

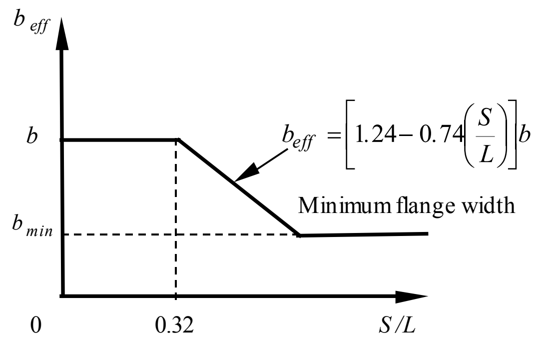

Figure C4.6.2.6.1-2 Effective Flange Width

For interior beams, the minimum effective flange width, b_{min} ~~effective flange width~~ may be taken as the least of:

- One-quarter of the effective span length;
- 12.0 times the average depth of the slab, plus the greater of web thickness or one-half the width of the top flange of the girder. ~~; or~~
- ~~The average spacing of adjacent beams.~~

For exterior beams, the minimum effective flange width, b_{min} ~~effective flange width~~ may be taken as one-half the effective width of the adjacent interior beam, plus the least of:

- One-eighth of the effective span length;
- 6.0 times the average depth of the slab, plus the greater of one-half the web thickness or one-quarter of the width of the top flange of the basic girder. ~~; or~~
- ~~The width of the overhang.~~

~~In calculating the effective flange width for closed steel and precast concrete boxes, the distance between the outside of webs at their tops will be used in lieu of the web thickness, and the spacing will be taken as the spacing between the centerlines of boxes.~~

~~For open boxes, the effective flange width of each web should be determined as though each web was an individual supporting element.~~

~~For filled grid, partially filled grid, and for unfilled grid composite with reinforced concrete slab, the "slab depth" used should be the full depth of grid and concrete slab, minus a sacrificial depth for grinding, grooving and wear (typically 0.5 in.).~~

When $S/L > 0.32$, the effective flange width calculated by Equation 1 is less than the full flange width as shown in Figure C2. When $S/L > 1.68$, especially for commonly used bent cap beams, the effective flange width calculated by Equation 1 is less than zero. Since the effective flange width can not logically be less than zero, based on the past successful practice the meaningful lower limit, the minimum effective flange width, b_{min}, is added in Equation 1. The minimum effective flange width, b_{min} should be checked when $S/L > 0.32$.

For negative moment region only, one possible alternative for determining the effective flange width is provided by Equation C2 is more accurate:

$$\frac{b_{eff}}{b} = 0.948 + 0.003\left(\frac{L}{S}\right) - 0.001\theta \leq 1.0 \qquad \text{(C4.6.2.6.1-2)}$$

where

,L = span length (ft), the lesser of the two span lengths if the two span lengths differ

θ = skew angle (^{o})

By comparing the results using the effective flange width obtained from the finite element analyses and a full slab width, the difference can be as high as 8.5%. By using Equation C2 the difference can be reduced to approximately 5.9% in the worst case investigated by Chen et al. *(2005)*.

Both the full physical flange width provision and Equation C2 were formulated based on finite element models that developed slab cracking in the negative moment sections under service loads. Thus, in negative moment regions these provisions should be used assuming the slab to be cracked, i.e., the composite section to consist of the beam section and the longitudinal reinforcement within the effective width of concrete deck.

A more refined analysis should be performed to determine the effective flange width when $\theta > 60^o$.

In calculating the effective flange width for closed steel and precast concrete boxes, ~~the distance between the outside of webs at their tops will be used in lieu of the web thickness, and~~ the girder spacing will be taken as the spacing between the centerlines of adjacent boxes.

For open boxes, the effective flange width of each web should be determined as though each web was an individual supporting element.

~~For filled grid, partially filled grid, and for unfilled grid composite with reinforced concrete slab, the "slab depth" used should be the full depth of grid and concrete slab, minus a sacrificial depth for grinding, grooving and wear (typically 0.5 in.).~~

(the last paragraph remains unchanged)

For integral bent caps, the effective flange width overhanging each side of the bent cap web shall not exceed six times the least slab thickness, or 1/10 the span length of the bent cap. For cantilevered bent caps, the span length shall be taken as two times the length of the cantilever span.

The provisions for the effective flange width for the integral bent cap are based on past successful practice, specified by Article 8.10.1.4 of the 2002 AASHTO Standard Specifications.

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4.6.3 Refined Methods of Analysis

4.6.3.1 GENERAL

Revise paragraph two as follows.

~~A structurally continuous railing, barrier, or median, acting compositely with the supporting components, may be considered to be structurally active at service and fatigue limit states.~~ Railings, barriers, and medians shall not be considered as structurally continuous.

4.6.3.2 Decks

Revise paragraph one as follows:

Unless otherwise specified, flexural and torsional deformation of the deck shall be considered in the analysis but vertical shear deformation may be neglected.

C4.6.3

C4.6.3.1

Add new text after the last sentence in paragraph two as follows:

This provision reflects the experimentally observed response of bridges. This source of stiffness has traditionally been neglected but exists and may be included, proved that full composite behavior is assured. However, Caltrans does not consider the appurtenances as a part of the structural design. Doing so would compromise the structural capacity if the appurtenance ever had to be removed.

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